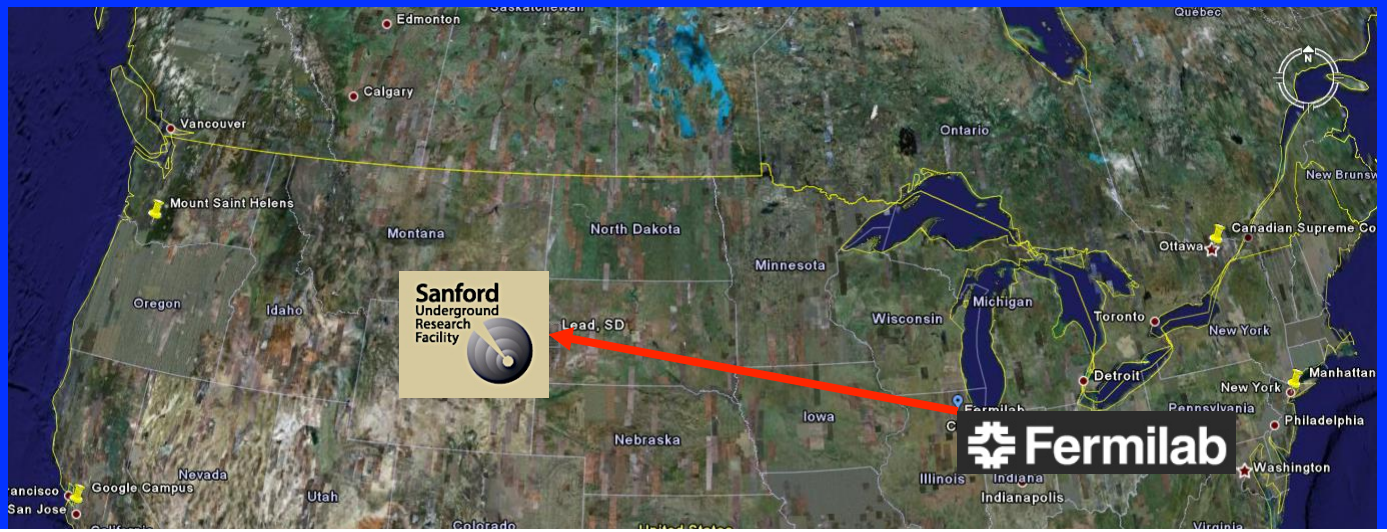
Santa Fe Meeting on Physics with the Long-Baseline Neutrino Experiment

Christopher Mauger
Los Alamos National Laboratory
25 April 2014

Welcome to Santa Fe

- Welcome to Santa Fe!
  - please pay
- We are at altitude (7000 feet)
- Workshop focus – LBNE
  - Medium-energy neutrino physics
    - Long-baseline neutrinos
    - Atmospheric neutrinos
  - Supernova neutrinos
- Discussion encouraged
- Dinner tonight – last call!

The Long-Baseline Neutrino Experiment



- LBNE consists of
  - an intense neutrino beam at Fermilab
  - near detector systems at Fermilab
  - a 34 kt liquid argon time-projection chamber (TPC) at Sanford Laboratory at 4850 foot depth – 1300 km from Fermilab
- When constructed, LBNE will have the longest manmade baseline of any neutrino experiment

Scientific Motivation

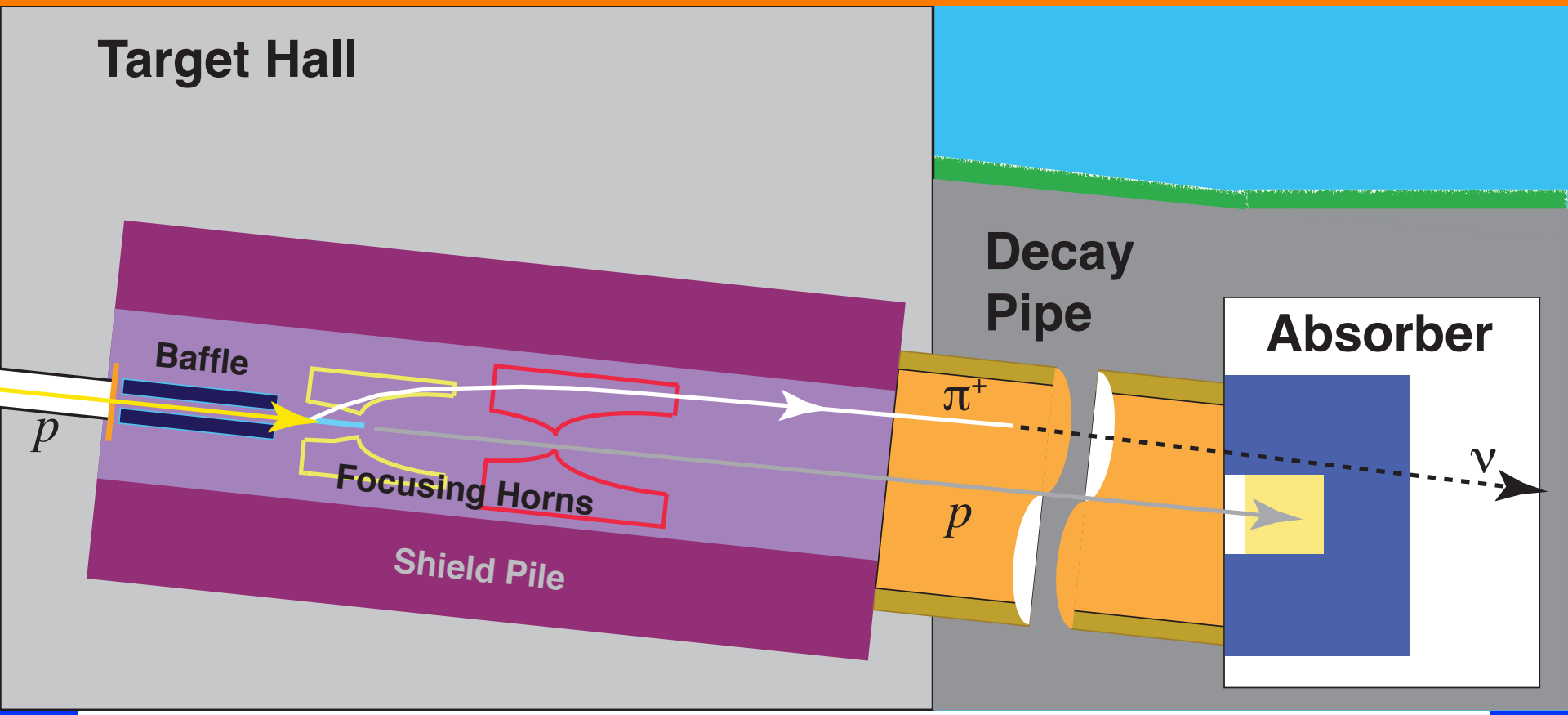
- Neutrino oscillations requires physics beyond the standard model
- Detailed studies of neutrino oscillations will allow us to answer important scientific questions:
  - What is the neutrino mass hierarchy?
  - Do neutrinos violate CP symmetry?
- High precision studies of neutrino oscillation phenomena allow us to test the three-flavor paradigm
  - Do sterile neutrinos exist?
  - Are there non-standard interactions (NSI)
- Building an experiment to address these issues with accelerator neutrinos enables much more science

Scientific Motivation

- Physics enabled by intense neutrino source and high-precision near neutrino detector
  - Precision electroweak tests
  - Searches for high Δm^2 neutrino oscillation physics
  - Searches for ``dark photons''
- Physics enabled by a large, underground far detector
  - Atmospheric neutrino studies
    - complementary oscillation physics studies
    - indirect WIMP searches
    - astrophysical neutrino searches
  - Burst supernova neutrino studies
    - complementary oscillation physics studies
    - supernova physics
  - Baryon number violation
    - SUSY, Grand Unified Theories
- And many others, see arXiv:1307.7335 – LBNE whitepaper

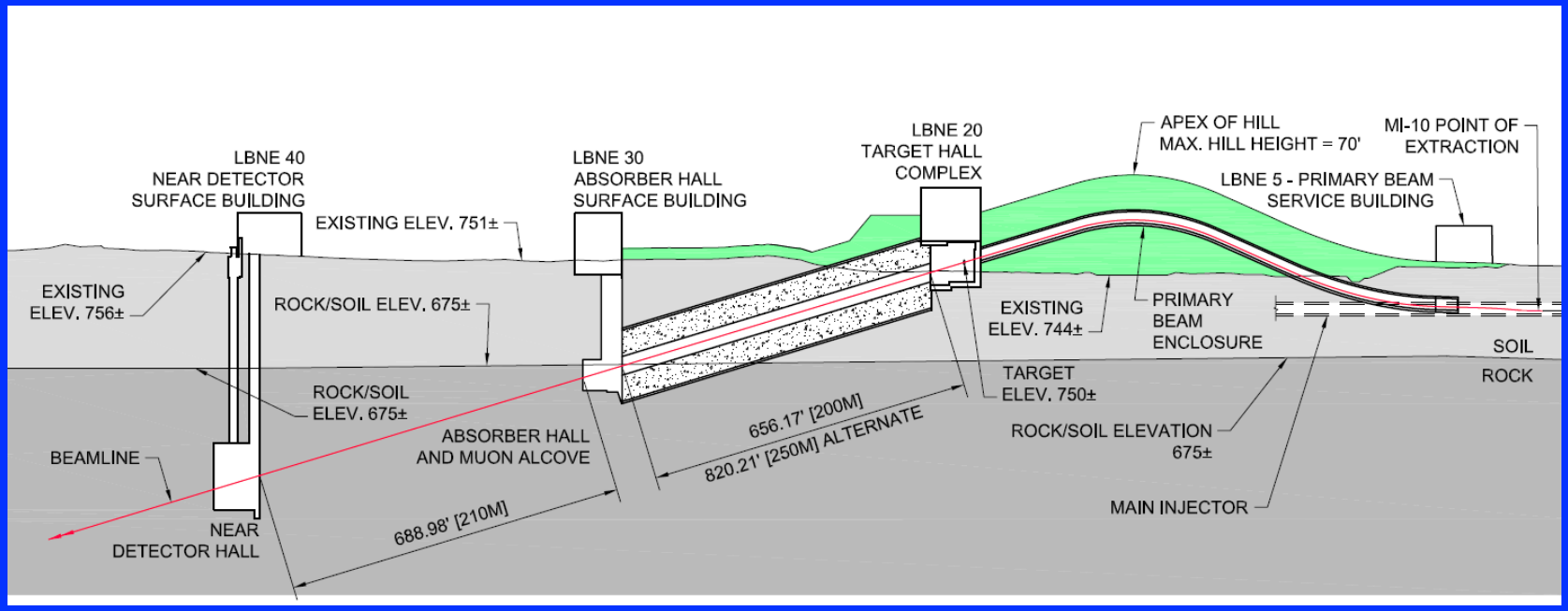
Layout on the Fermilab site

Layout of LBNE: Neutrino Beam



- Conventional neutrino beam from charged pion decay – beam power of 1.2 MW
- All permanent fixtures rated for 2.3 MW operation

Cross-section of NDS Layout



- Two sets of detector systems:
  - Measure muons after the absorber
  - Measure neutrinos

Measurements of muons post-absorber

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

- $E_\nu=(0\text{-}0.43)E_\pi$
- $E_\mu=E_\pi-E_\nu=(0.57\text{-}1.0)E_\pi$

Cherenkov Detectors:

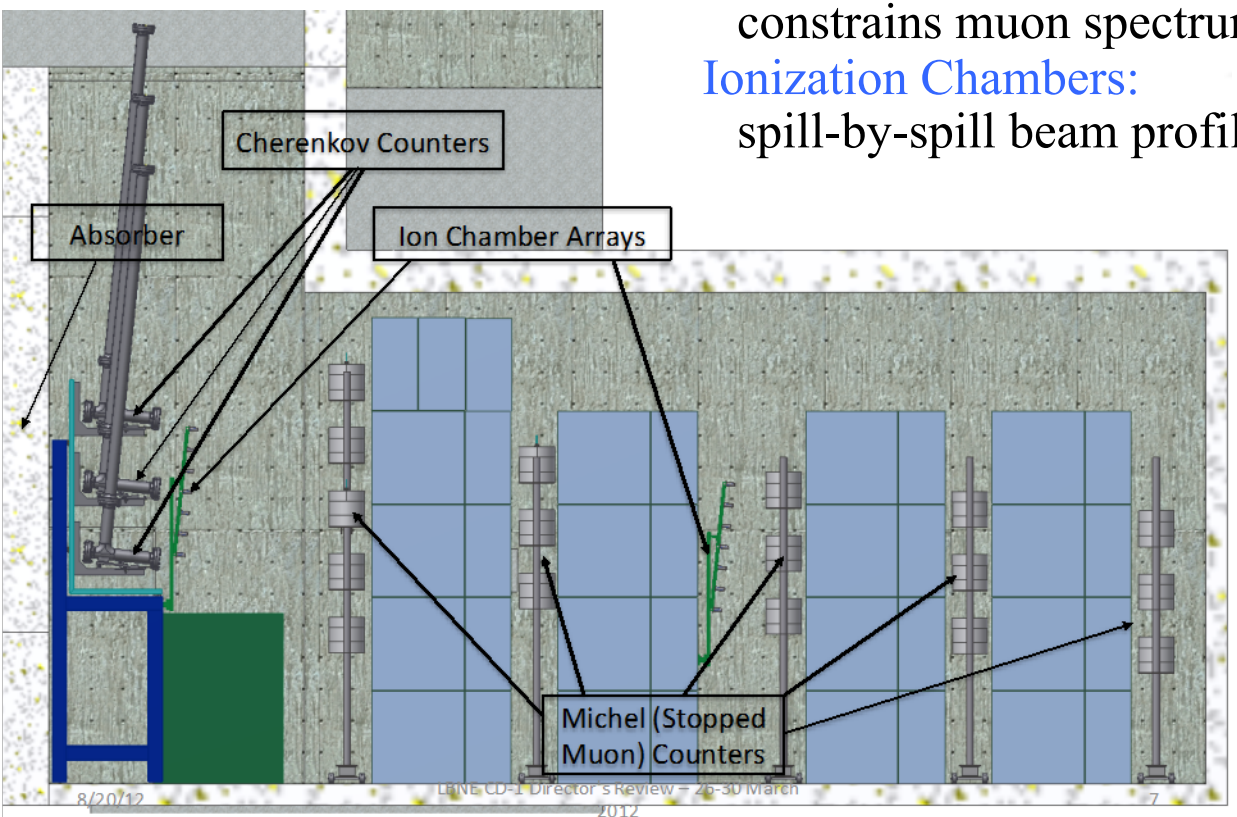
measure all muons above a variable threshold
constrains muon spectrum (correlated with E_ν)

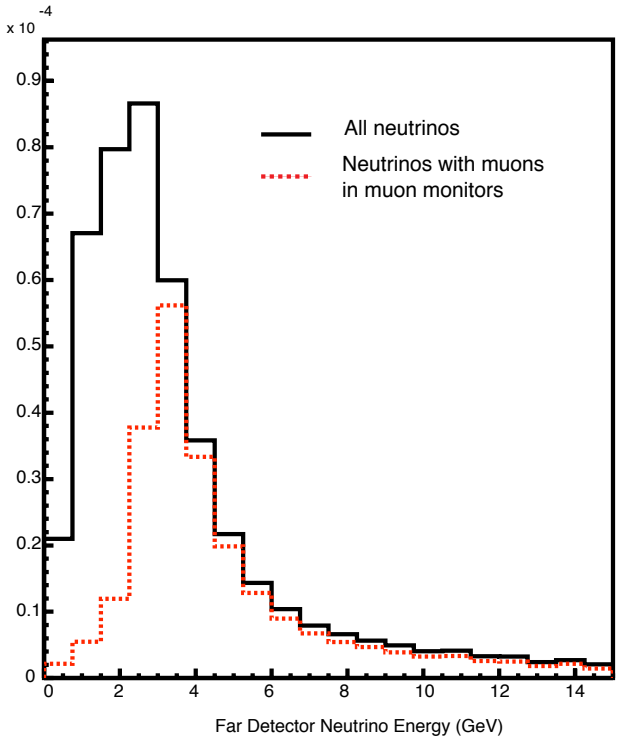
Michel Decay Detectors:

measure muons that stop at a given depth in material
constrains muon spectrum

Ionization Chambers:

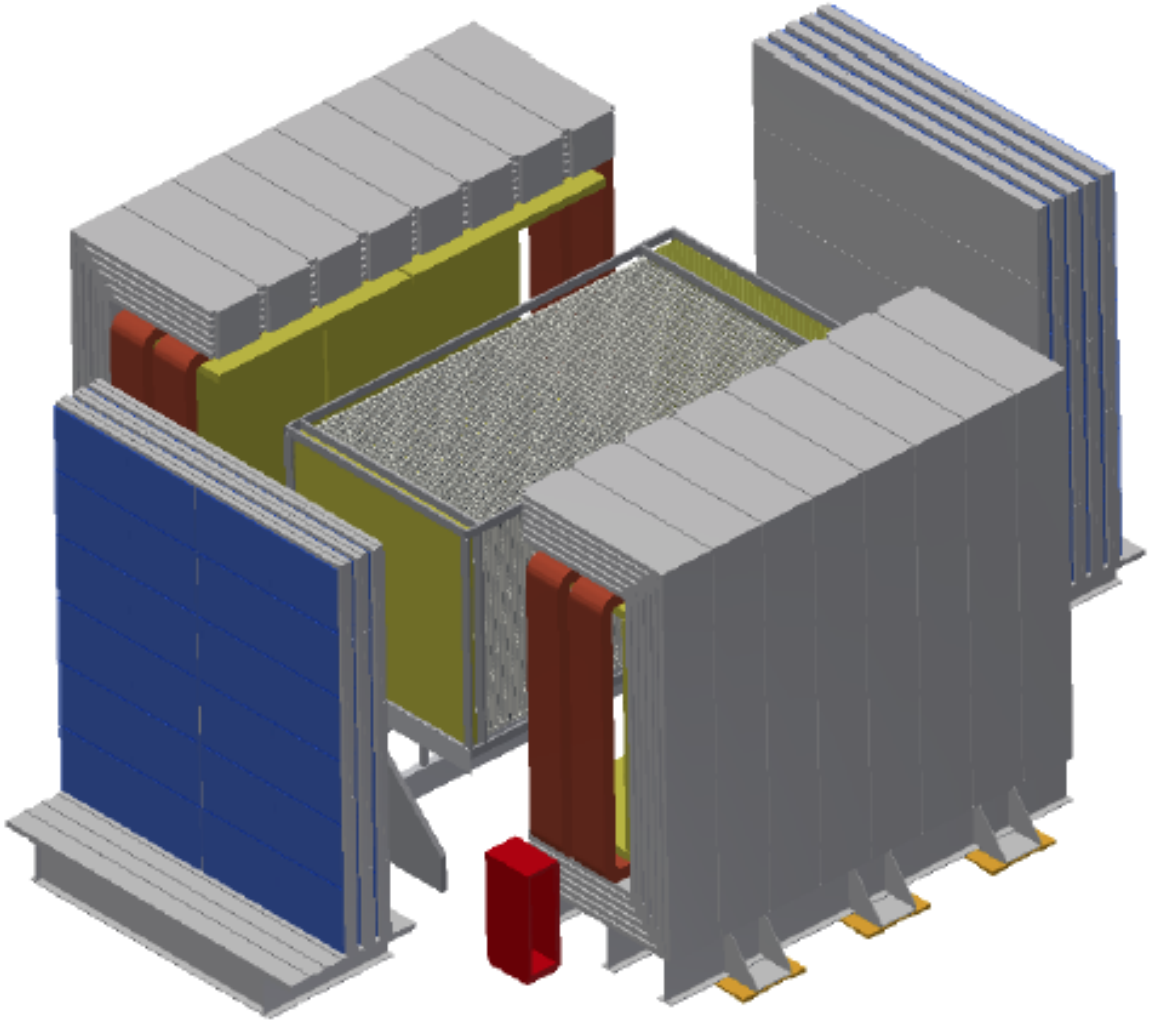
spill-by-spill beam profile





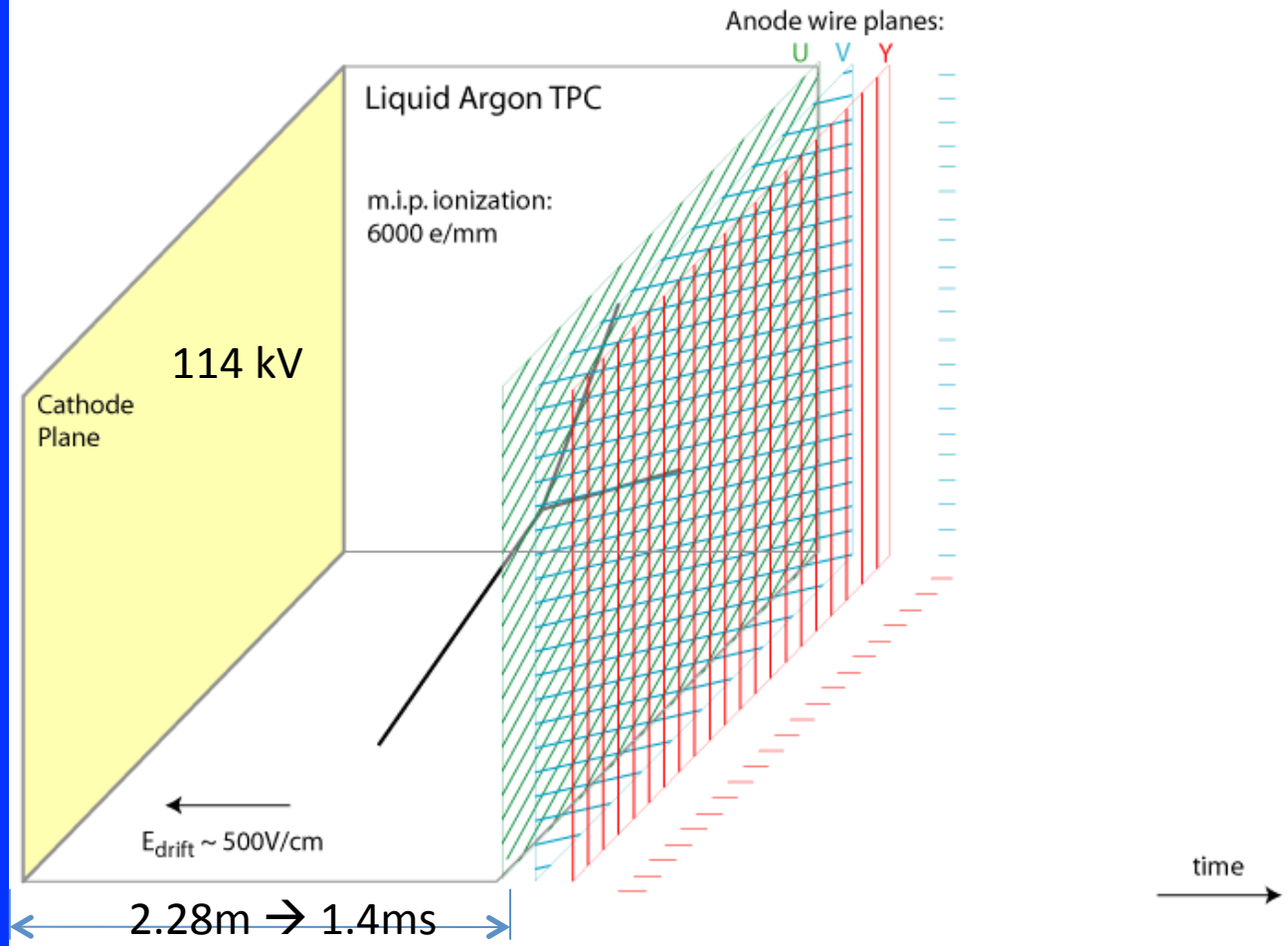
Near Neutrino Detector

- High precision straw-tube tracker with embedded high-pressure argon-gas targets
- Philosophy
  - make high-precision, high-statistics measurements of neutrino interactions with argon (far detector target nucleus)
  - measure inclusive and exclusive cross-sections to build and constrain models to predict the event signatures at the far site *and correlate them with true neutrino energy*
  - make detailed studies of electron (and muon) neutrino and anti-neutrinos separately

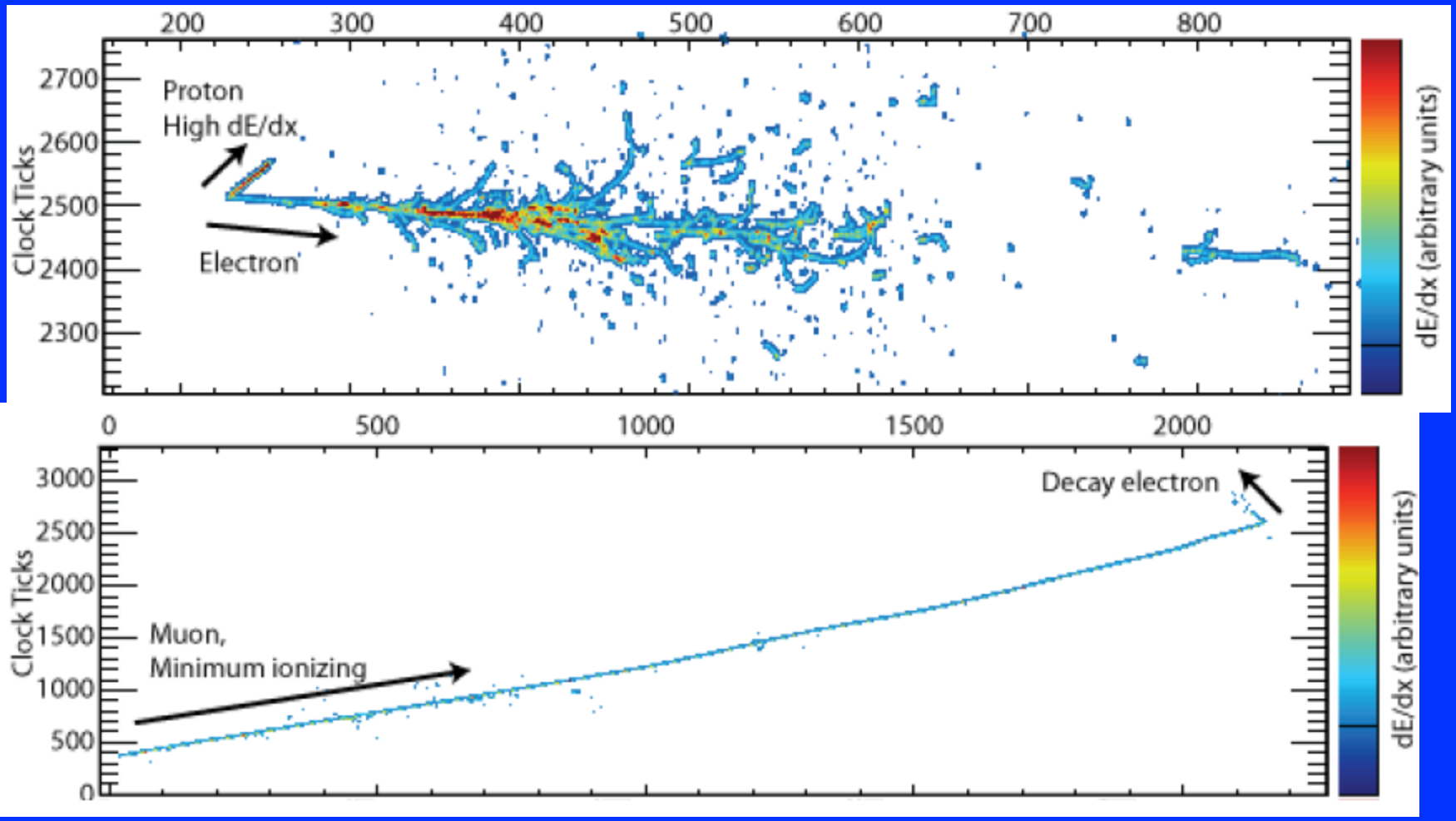


Liquid Argon Time-Projection Chambers (TPCs)

MIP dE/dx = 2.2 MeV/cm
→ ~ 1fC/mm @ 500 V/cm
→ ~1 MeV/wire



Liquid Argon TPC Performance



Far Detector Layout

34kt fiducial mass LAr TPC
at 4850'L (1.5km)
50kt total Ar mass